Utkarsha L. Mohite* and Hirenkumar G. Patel

Robust controller for cancer chemotherapy dosage using nonlinear kernel-based error function

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Abstract: It is well-known that chemotherapy is the most significant method on curing the most death-causing disease like cancer. These days, the use of controller-based approach for finding the optimal rate of drug injection throughout the treatment has increased a lot. Under these circumstances, this paper establishes a novel robust controller that influences the drug dosage along with parameter estimation. A new nonlinear error function-based extended Kalman filter (EKF) with improved scaling factor (NEF-EKF-ISF) is introduced in this research work. In fact, in the traditional schemes, the error is computed using the conventional difference function and it is deployed for the updating process of EKF. In our previous work, it has been converted to the nonlinear error function. Here, the updating process is based on the prior error function, though scaled to a nonlinear environment. In addition, a scaling factor is introduced here, which considers the historical error improvement, for the updating process. Finally, the performance of the proposed controller is evaluated over other traditional approaches, which implies the appropriate impact of drug dosage injection on normal, immune and tumor cells. Moreover, it is observed that the proposed NEF-EKF-ISF has the ability to evaluate the tumor cells with a better accuracy rate.

Keywords: chemotherapy; controller; drug dosage; error function; extended Kalman filter.

Introduction

As cancer is turning out be a dreadful disease [1–3], it is necessary to improve the diagnostic benefits of the treatment. Moreover, it is significant to compute the efficiency of the chemotherapy plan and its viability. In fact, chemotherapy [4–6] is a traditional technique that is used for treating cancer in medical practice [37–40]. The deliverance of chemotherapy drugs is found to be a better therapeutic approach and it has attained a worldwide consideration these days. Nowadays, engineering science has contributed a lot to this research by formulating several numerical designs, which demonstrates the impact of chemotherapeutic drugs [7–9] and its dose.

These approaches were extensively deployed to develop and analyze a variety of drug controlling techniques [10–12]. These in “silico trials” are cost-efficient and it assists engineers and clinicians to analyze the consistency of new approaches for drug dosage in medical pharmacology. Nowadays, the combined usage of siRNAs and chemotherapy drugs [13, 14] remains a better treatment for cancer and it has gained much attention. The 2D-based models of siRNA and chemotherapy drug [15, 16] intend to minimize the side effects of the drugs and it also minimizes the adverse harms occurring to normal cells. On the other hand, after repetitive chemotherapy [17, 18], the severe undesirable effects resulting from chemo agents weaken the outcome, thus resulting in diagnostic failure [19–21, 41, 42].

In addition, Kalman filtering techniques play an essential role in estimating the dynamic states and it enhances the estimation accuracy. It also improves the precision and temporal resolution, thus ensuring a better estimation of the drug dosage levels [22–24]. However, a major issue in exploiting Kalman filter lies in setting up the covariance matrixes. Therefore, EKF is introduced that enhances the accuracy of dynamic state estimation. In addition, EKF could be applied for estimating the immune cells, and it can adjust the dosage of drugs and thus control the normal, immune and tumor cells in chemotherapy [25].

The major contribution of this paper is depicted below.

(1) This paper intends to present a novel robust controller that influences the drug dosage together with parameter estimation.
(2) Here, a novel NEF-EKF-ISF is introduced and the updating process is done depending on the prior error function, though scaled to a nonlinear environment.

***Corresponding author: Utkarsha L. Mohite,** Assistant Professor, Department of Electrical Engineering, SVNIT, Surat, India, E-mail: utkarshalmohite@gmail.com
Hirenkumar G. Patel, Department of Electrical Engineering, SVNIT, Surat, India